REMARKS

Applicants acknowledge, with appreciation, the allowance of claims 31-36. Claims 1-37 are currently pending, with claims 1, 31, 33 and 35 being in independent form. Independent claim 1 has been amended. Support for the amendment to claim 1 may be found at pg. 5, lines 4-5 of the originally filed specification. No new matter has been added. Reconsideration of the application, as amended, is respectfully requested.

Claims 1-30 and 37 were rejected under 35 U.S.C. §103(a) as unpatentable over Carrier Screening Effects in Photoluminescence Spectra of InGaAsP/InP Multiple Quantum Well Photovoltaic Structures, Applied Physics Letter, Vol. 79, Number 3, 16 July 2001 ("*Raisky*") in view of U.S. Pub. No. 2002/0096675 ("*Cho*"). For the following reasons, it is respectfully submitted that all claims of the present application are patentable over the cited reference.

Independent claim 1 has been amended to recite the limitation "an i type semiconductor layer, comprising a multiple quantum well region in which electrons are transported through the multiple quantum region by sequential resonant tunneling". The claimed invention is directed to a sequential resonant tunneling p-i-n device in which sequential tunneling is used. Therefore, the foregoing amendment does not present a new issue that would require further consideration and/or search. No new matter has been added.

Raisky relates to observing the effect of carrier screening on the photoluminescence (PL) in a multiple quantum well (MQW) InGaAsP/InP *p-i-n* photodiode (see pg. 430, 1st paragraph).

Cho relates to (ISB) optical devices that operate at wavelengths shorter than about 1.7 μm (see paragraph [0002]). *Cho* (paragraph [0011], lines 1-6) teaches an ISB optical device that comprises first quantum well (QW) interior regions having upper and lower energy states between which ISB transitions take place, and superlattice (SL) barrier regions interposed

between the first QW interior regions. *Cho* (paragraph [0011], lines 6-8) states, "the SL barrier regions include second barriers and second QW interior regions, with the second QW interior regions being interposed between the second barrier regions". *Cho* (paragraph [0011], lines 9-12) further states, "the first QW interior regions and the SL barrier regions are configured to produce an energy gap between upper and lower states that is larger than the energy of a 1.7 μm wavelength photon".

The Examiner (pg. 4) of the April 4, 2005 Office Action states:

> Raisky teaches a room temperature p-I-n photovoltaic structure comprising InGaAsP/InP materials that absorb at particular wavelengths. The difference between the claims and Raisky is GaN based material. This difference is not patentable because Cho teaches the GaN based material system for its increased conduction band offset and response at more desirable wavelength ranges. Accordingly, it would have been obvious to have practiced a p-I-n photovoltaic resonant tunneling structure with GaN based materials from the suggested teaching of Raisky and Cho.

The Examiner (pg. 2) of the September 26, 2005 Office Action states:

> The previous rejection (in the April 4, 2005 Office) still applies. The new limitations are not patentable as Raisky teaches quantum wells of the same thickness and barriers of the same thickness.
>
> . . . .
>
> Cho suggests GaN material for its increased conduction band offset and response at more desirable wavelengths. Raisky suggests same MQW quantum well widths for excellent photovoltaic operation.

With respect to the foregoing statements, Applicants respectfully assert that the combination of *Raisky* and *Cho* fails to achieve the invention recited in amended independent claim 1. That is, *Raisky* and *Cho*, individually or combination, fail to teach or suggest "a sequential resonant tunneling p-i-n device for use as a photodetector or optically pumped emitter … comprising, *inter alia*, an i type semiconductor layer, comprising a multiple quantum well

region in which electrons are transported through the multiple quantum region by sequential resonant tunneling," as recited in amended independent claim 1.

The claimed invention can output multiple infra red photons per incident photon when operating as an optically pumped infrared emitter. The claimed sequential resonant tunneling p-i-n device emits photons created by relaxation of electrons photogenerated by interband excitation, and these emission can generate M IR photons for each incident photon passing through N quantum wells, where $M \leq N$. The combination of *Raisky* and *Cho* fails to teach or suggest such a single-pump and multiple-IR-emission device. In fact, any combination of *Raisky* and *Cho* would simply fail to yield a device that operates identically to Applicants' claimed sequential resonant tunneling p-i-n device, which includes "an i type semiconductor layer, comprising a multiple quantum well region in which electrons are transported through the multiple quantum region by sequential resonant tunneling," as recited in amended independent claim 1.

The claimed invention utilizes sequential resonant tunneling in quantum wells (see, e.g., claims 1, 21-25 and 30-36). *Raisky* and *Cho*, individually or in combination, fail to teach or suggest a device that would include this claimed feature. Moreover, absent an impermissible hindsight analysis based on Applicants' present disclosure, a person having the ordinary level of skill in the art would not be motivated to produce Applicants' claimed sequential resonant tunneling p-i-n device, because (i) neither *Raisky* nor *Cho* make any mention of sequential tunneling; and (ii) advanced knowledge of both semiconductor physics and quantum mechanics is needed to correctly understand sequential resonant tunneling, related carrier transports mechanisms and their applications in photodetector emitters. The combination of *Raisky* and *Cho* fails to provide this advanced knowledge.

The claimed device cannot be achieved by simply modifying the *Raisky* device based on the quantum well structures taught in *Cho*, because there are several differences between Applicant's claimed sequential resonant tunneling p-i-n device and the devices disclosed in *Cho*.

Firstly, *Cho* (paragraph [0037], lines 5-7; Figs. 1A and 1B) teaches active regions that are located between a pair of barrier regions. *Cho* (paragraph [0037], lines 7-9) states, the "active regions include at least one quantum well [(AR QW)]; e.g., a single QW or multiple, coupled QWs". *Cho* (paragraph [0037], lines 12-14) further states, "transitions take place between an upper energy level or state 12.2 and a lower state 12.1 both of which are confined in the AR QW. *Cho* (paragraph [0037], lines 15-18) also teaches that each principal barrier region comprises a superlattice (SL), which includes second interior QW regions 14.1 separated from one another by second barrier regions 14.2. Thus, *Cho* teaches the use of two quantum wells, where one QW is located in an interior region and the other QW is located in an "exterior region". In contrast, the claimed device utilizes a single "i type semiconductor layer, comprising a multiple quantum well region in which electrons are transported through the multiple quantum region by sequential resonant tunneling comprising a number of III-nitride multiple quantum well layers of the same thickness and which are undoped or semi-insulating, between the p type and the n type semiconductor layers," as recited in amended independent claim 1.

Secondly, *Cho* (paragraph [0041] teaches that the AR QWs are preferably wider than the SL QWs. In contrast, the well widths of the MQW structure of the claimed sequential resonant tunneling p-i-n device are identical, as recited in amended claim 1.

Lastly, *Cho* (paragraph [0011], lines 4-8) teaches barrier regions comprised of a super latticed structure. However, Applicants' claimed sequential resonant tunneling p-i-n device uses a single layer for each barrier, i.e., a p type semiconductor layer and an n type semiconductor

layer, as recited in amended independent claim 1. Thus, the combination of *Raisky* and *Cho* would fail to achieve Applicants' device recited in amended independent claim 1. With respect to semiconductor devices, such substantial differences between the well and barrier structures achieved by the combination of *Raisky* and *Cho* and the structure of Applicants' claimed device results in devices that operate differently from each other. In view of the foregoing, amended independent claim 1, is patentable over the combination of *Raisky* and *Cho*, individually or in combination. Therefore, reconsideration and withdrawal of the rejection under 35 U.S.C. §103(a) are in order, and a notice to that effect is respectfully requested.

In view of the patentability of independent claims 1, 31, 33 and 35, for the reasons set forth above, dependent claims 2-30, 32, 34, 36 and 37 are all patentable over the prior art. Moreover, each of these claims includes features which serve to even more clearly distinguish the invention over the applied references.

For example, the sequential tunneling of the claimed invention operates under a predetermined bias in order to reach the condition in which sequential tunneling can occur, and a specific experiment must be performed in order to determine this working bias. The present inventors propose to determine this bias by measuring a current-voltage profile of the claimed device. A peak electrical current will appear at a certain bias to obtain the value of the working bias, which is achieved by the measuring the current-voltage profile of the device. Dependent claims 21-25 are directed to determining such a working bias. The combination of *Raisky* and *Cho* fail to teach or suggest the determination of a working bias. Thus, dependent claim 22 is patentable over the combination of *Raisky* and *Cho* for this additional reason.

Sequential resonant tunneling only occurs in a certain biased condition, where the energy state of a ground state in each quantum well layer is aligned with the energy state of a first

excited state in the adjoining well layer, as further recited in independent claim 22 and illustrated in Fig. 4 of the present disclosure. The combination of *Raisky* and *Cho* fail to teach or suggest this aspect of claimed invention. Thus, dependent claim 22 is patentable over the combination of *Raisky* and *Cho* for this additional reason.

The claimed invention utilizes compounds in InAlGaN, which causes the claimed device to work at a wider wavelength range, as recited in dependent claimed . The combination of *Raisky* and *Cho* is silent with respect to this aspect of claimed invention. Thus, dependent claim 20 and 37 are patentable over the combination of *Raisky* and *Cho* for this additional reason.

Based on the foregoing amendments and remarks, this application is in condition for allowance. Early passage of this case to issue is respectfully requested.

Respectfully submitted,

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Dated: January 30, 2006